(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : **0 671 776 A1**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number : **95301110.3**

(22) Date of filing : **22.02.95**

(51) Int. Cl.^{6} : **H01P 5/18**

(30) Priority : **07.03.94 US 206996**
07.12.94 US 350600

(43) Date of publication of application :
13.09.95 Bulletin 95/37

(84) Designated Contracting States :
DE FR GB

(71) Applicant : **AT & T Corp.**
32 Avenue of the Americas
New York, NY 10013-2412 (US)

(72) Inventor : **Veitschegger, William Kerr**
8556 Appleridge Circle
Pickerington, Ohio 43147 (US)

(74) Representative : **Watts, Christopher Malcolm Kelway, Dr. et al**
AT&T (UK) Ltd.
5, Mornington Road
Woodford Green Essex, IG8 0TU (GB)

(54) **Multiplanar hybrid coupler.**

(57) A microwave directional coupler comprises a dielectric coupler board (15), elongated metallic flat conductors (25a, 25b) deposited on front and back surfaces (20a, 20b) of the board and having respective central strip portions (26a, 26b) electrically broadside coupled with each other through the board, and respective right and left hand lead portions (28a, 27b), (27a, 28b) terminating in ports 29, 49 at the bottom margins (22a, 22b) of the board. Metallic ground plane regions (50, 51, 52) cooperate with those flat conductors to form corresponding microwave transmission lines comprising respective signal conductors provided by said flat conductors and respective grounded conductors provided by said regions. The ground plane regions are in the form of expanses of metallic layers deposited on the same surfaces of the board as are such flat conductors. Ground plane regions on opposite sides of the board are electrically connected by plated-through holes (80-89, 90-98) passing through the board. The coupler board is vertical and stands on a dielectric support board (110) having metallic connector strips (120-123) thereon for connecting the ports of the flat conductors to external circuit elements (134).

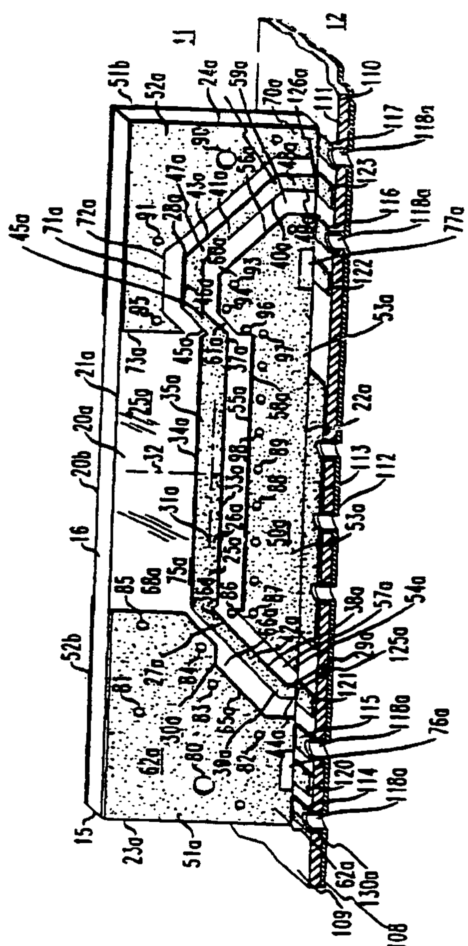


FIG. 2

EP 0 671 776 A1

Field of the Invention

This invention relates generally to microwave directional coupler devices for electromagnetically coupling a plurality of two-conductor transmission lines, each comprising signal conductor means and ground conductor means, to provide for transfer of microwave energy between the two lines.

U.S. Patent 4,882,555 issued November 21, 1989 in the name of M. N. Wong for "Plural Plane Waveguide Coupler" discloses microwave coupler comprising circuit board in the shape of a square to have four peripheral margins. The board comprises a dielectric substrate having top and bottom surfaces, and top and bottom metallic pads centrally located on, respectively, those top and bottom surfaces and disposed opposite each other through the board to be broadside coupled with each other. Two top metallic strips extend from junctions thereof with opposite ends of the top pad to two respective ports at the top and bottom margins of the board. Two bottom metallic strips extend from junctions thereof with opposite ends of the bottom strip to two respective ports at the left and right margins of the board. The pad and strips on each of the top and bottom surfaces of the substrate are bordered by slots by which they are spaced from expanses of metallic sheets on those surfaces and covering the entire areas thereof outside of said slots.

The Wong coupler has the disadvantage that its four ports are each at a different one of the four peripheral margins of Wong's circuit board so as to make it difficult and expensive to couple the Wong coupler to external microwave circuitry. Another disadvantage of the Wong coupler is that it is wasteful of space.

Summary of the Invention

The foregoing and other disadvantages of the Wong coupler are overcome accordirng to the invention hereof by improved coupler devices of the character set forth by the appended claims.

Brief Description of Drawings

For a better understanding of the invention, reference is made to the following description of an exemplary embodiment thereof, and to the accompanying drawings wherein:

FIG. 1 is a plan view of an improved directional coupler according to the invention and comprising a coupler assemblage and a support assemblage which mounts, and provides connections for, the coupler assemblage, such support assemblage being shown broken-away in FIG. 1;

FIG. 2 is an isometric view of the front side of the FIG. 1 device;

FIG. 3 is an isometric view of the back side of the FIG. 1 device;

FIG. 4 is a front schematic, elevational view which is a superposition of respective elevational views which would be seen of the front and back sides of the coupler assemblage, if the viewer were to look, in the front-to-back transverse direction, towards, through and past such assemblage;

FIG. 5 is a "see-through" front elevation view which is like FIG. 4, but in which elements on the front and back sides of the coupler assemblage are shown by, respectively, solid lines and dash lines;

FIG. 6 is an enlarged view of the circled left-hand portion of FIG. 5;

FIG. 7 is an enlarged view of the circled right-hand portion of FIG. 5; and

FIGS. 8 and 9 are fragmentary enlarged cross-sectional views of portions of the FIG. 1 coupler assemblage as such portions would be seen if the coupler board of the assemblage were to be horizontal with its front surface being on top, such figures being schematic representations of operating characteristics of such assemblage and not being to scale, and the showings of which are not to be taken as necessarily being quantitatively accurate.

In the description which follows, elements which are counterparts of each other are designated by the same reference numerals having different alphabetical suffixes to designate different of those elements, and it is to be understood that a description of any of those elements shall, unless otherwise indicated by the context, be taken as being also applicable to any counterpart of that element. Moreover, while the invention may be described and/or claimed in terms of coordinates such as, say, "vertical" and "horizontal", the invention is not limited to any particular orientation thereof.

Detailed Description of the Embodiment

Referring now to FIGS. 1 and 2, the reference numeral 10 designates a directional coupler device which is a representative embodiment of the invention hereof, and which comprises a coupler assemblage 11 and a connector assemblage 12 which mounts component 11 and provides connections therefor.

The coupler assemblage 11 comprises a substrate or body 111 of dielectric material which in the device 10 takes the form of a planar rectangular coupler board 15 constituted of dielectric material 16. Board 15 extends in the transverse dimension which coincides with the direction of its thickness, and the board also extends in the longitudinal and lateral dimensions which are normal to the transverse dimension. In the figures hereof, the longitudinal and trans-

verse dimensions are horizontal whereas the lateral dimension is vertical.

The board 15 has two parallel planar surfaces 20a and 20b which are on transversely opposite sides of the board to be spaced from each other by the thickness between those surfaces of the board's dielectric material. Those surfaces 20a and 20b are front and back surfaces, respectively in relation to one direction in the transverse dimension. That direction is hereinafter referred to as the front-to-back transverse direction and will be used hereinafter as a reference direction in describing various elements of the coupler device and, in particular, in describing left-right relations therebetween.

Considering now the front surface 20a, (FIG. 2) it is rectangular in shape and has a top peripheral margin 21a, a bottom peripheral margin 22a and side peripheral margins 23a and 24a which are left and right margins, respectively, in relation to the front-to-back transverse direction. Surface 20a has thereon an elongated flat metallic conductor 25a of electrical energy which is referred to herein as the front conductor and which in device 10 is provided by a metallic layer in the form of a thin layer of copper clad on surface 20a. The front conductor 25a comprises, as portions thereof, a front central strip 26a and two leads 27a and 28a which are, respectively, left and right front leads in relation to the front-to-back transverse direction.

Front central strip 26a has a horizontal centerline 31a and is axially symmetrical about a vertical axis 32 for board 15 and has a central location on front surface 20a in that the strip is located vertically intermediate the top and bottom margins 21a, 22a and horizontally intermediate its left and right side margins 23a, 24a. The strip 26a has lower and upper edges 33a, 34a and an expanse 35a between those edges, and the strip extends longitudinally between left and right hand ends 36a, 37a thereof at which the leads 27a and 28a have respective junctions with the strip 26a.

The leads 27a, 28a have respective edges 38a, 39a and 40a, 41a and respective expanses 42a, 43a between those edges, and those leads are, (FIG. 2), narrower in breadth than central strip 26a. Outward of its junction with the center strip 26a, the left hand front lead 27a has a downwardly slanting section 30a which extends substantially linearly downward and longitudinally outward, to slant, at a downward angle to center line 31a, to a vertical section 44a of lead 27a extending down to a lower end or termination 29a of the section at the bottom margin 22a of the front surface 20a, such termination 29a constituting a port for lead 27a. The right hand front lead 28a, however, extends, outward of its junction with the center strip 26a, first upwardly and longitudinally outward over a section 45a of the lead to slant at an upward angle to centerline 31a. Then the lead has a level section 46a which is followed by a section 47a slanting downwards and outwards to a vertical lead section 48a extending down to a lower end or termination 49a of section 48a at the bottom margin 22a of the front surface 20a, such termination constituting a port for the lead 28a. Lead sections 30a and 44a form a dogleg lower portion for lead 27a while lead portions 47a and 48a form a dogleg lower portion for lead 28a.

The front surface 20a has thereon not only the strip conductor 25a but, also, three metallic expanses 50a, 51a and 52a constituting respective ground plane regions and provided by a metallic layer in the form of a thin copper layer clad on that surface. Region 50a is a central front region disposed in a central portion of board 15 below the front central strip 26a and longitudinally between the left and right front leads 27a and 28a. On its lower side, region 50a extends down to a termination 53a thereof at the bottom margin 22a of the surface 20a. A notch-shaped void 77a extends from that bottom margin into the metallic expanse of region 50a. On its upper side, the region 50a has edges 54a, 55a, 56a which are separated by gaps 57a, 58a, 59a from respectively the lower edge 38a of lead 27a, the lower edge 33a of central strip 26a and the lower edge 40a of the lead 28a. As shown by FIG. 2 the region 50a on its right hand side has an upwardly projecting head 60a of such shape that, near the junction, at the strip end 37a, of lead 28a with central strip 26a, the gap 59a between the edge 56a of region 50a and the lower edge 40a of lead 28a has a pinch 61a and is much narrower in width at that pinch than the width of gap 59a at a greater distance along lead 28a away from that junction.

The region 51a is a left front region disposed on surface 20a leftward of left front lead 27a and extending down to a termination 62a of the region at the bottom margin 22a of front surface 20a. A notch-shaped void 76a extends from that bottom margin into the metallic expanse of region 51a. Region 51a has a slanting angulated edge 65a separated by a gap 66a from the upper edge 39a of the lead 27a. That edge 65a is shaped to provide, near the junction, at strip end 36a, of lead 27a with strip 26a, a pinch 67a at which the width of gap 66a is much narrower than it is farther away along lead 27a from that junction. The slanting edge 65a intersects at about the level of the top edge 34a with an edge 68a of region 51a rising wholly vertically to the top margin 21a of front surface 20a.

The region 52a is a right front region disposed on surface 20a rightward of right front lead 28a and extending down to a termination 70a of the region at the bottom margin 22a of the surface 20a. The region 52a has an angulated edge 71a separated by a gap 72a from the upper edge 41 a of the lead 28a. At a point above the junction, at strip end 37a, of that lead with central strip 26a, the edge 71a intersects with an edge 73a of region 52a rising wholly vertically to the

top margin 21a of front surface 20a. The vertical edges 68a and 73a of, respectively, regions 51a and 52a and the upper horizontal edge 34a of central strip 26a define and bound on surface 20a a relatively large bare area 75a above the central strip.

The coupler assemblage 11 has formed therein a plurality of plated-through holes or vias of which ones are designated in FIG. 2 as holes 80-89 and others as holes 90-98 while still others remain undesignated. Hole 89 lies on the vertical axis 32 of board 15, and holes 80-88 and 90-98 lie, respectively to the left and right of that axis. Holes 80-88 and 90-98 are symmetrically distributed relative to axis 32. That is, holes 85 and 95, say, are at the same height and are equidistant from axis 32, the same is true of holes 87 and 97, and so on. Each of holes 80-89 and 90-98 and the undesignated holes has a front opening in one of the front ground plane regions 50a, 51a, 52a, and each such hole passes transversely from that opening and region through board 15 and then through a metallic back ground plane region (later described in more detail) on the back surface 20b of the board to a back opening of such hole in that back ground plane region. Further, the interior bounding wall provided for each hole by the dielectric material 16 of board 15 is coated with copper to provide a conductive path for electricity through that hole. Thus, each of plated-through holes 80-89 and 90-98 and the undesignated holes electrically connects a metallic ground plane region on the front of board 15 to a metallic ground plane region on the back of the board. More details will be later given of such connections.

The coupler assemblage 11 is mounted on the top of connector assemblage 12 and stands vertically up from that latter assemblage. That connector assemblage comprises a connector substrate or body of dielectric material which in device 10 takes the form of a mother or support board 110 having lower and upper surfaces 108, 109. The connector or support board 110 and the coupler board 15 together provide an insulative base unit for carrying the metallic elements of the directional coupler device 10. The board 110 has on its bottom surface 108 a metallic layer 112 which may be formed, say, of copper clad on that surface and which provides the main ground plane region on board 110. The board 110 also, has, however, on its upper surface 109 a central rectangular expanse provided by a layer of copper coated on that upper surface and providing a supplemental ground plane region 113. The longitudinal extent of that region is preferably as shown in FIG. 3 rather than FIG. 2.

Similar smaller supplemental ground plane regions 114, 115 and 116, 117 are provided to the left and right of, respectively, the central supplemental ground plane region 113. The upper ground plane regions 113-117 of board 110 are electrically connected to its lower ground plane region 112 on the front side of device 10 by plated-through holes 118a passing through board 110 to the front of the vertical coupler assemblage 11.

For purposes of electrically connecting the coupler assemblage 11 to circuitry external to device 10, the support board 110 has four parallel metallic connector strips 120, 121, 122, and 123 extending transversely on the upper surface 109 of the board. The four strips 120, 121, 122 and 123 register at the front side of coupler assemblage 11, and in its longitudinal dimension, with, respectively, the center of void 76a, the termination 29a of the lead 27a of strip conductor 25a, the center of void 77a, and the termination 49a of the lead 28a of strip conductor 25a. Because connector strips 120 and 122 are isolated by voids 76a and 77a from the ground plane regions 51a, 50a on the front side of coupler board 15, those strips can and do pass beneath the front side of the board 15 without being grounded by coming into contact with one of those ground plane regions.

The connector strips 121 and 123 are, however, not so electrically isolated from the coupler board 15 on its front side. Rather those connector strips 121 and 123 are electrically connected by solder beads 125a and 126a to, respectively, the terminations 29a and 49a of the left and right front leads 27a and 28 of the front strip conductor 25a. Other solder beads 130a are used to electrically connect the front ground plane regions 50a, 51a, and 52a on the coupler board 15 to the ground plane regions 113-117 on the upper side of support board 110.

Turning now to FIG. 3 which shows the back side of device 10, the back surface 20b of the coupler board 15 has thereon (a) a flat elongated metallic conductor 25b comprising, as portions thereof, a back central strip 26b and two back leads 27b and 28b, and (b) metallic expanses 50b, 51b and 52b constituting respective back ground plane regions on that back surface. The back surface 20b and the elements 25b-28b and 50b-52b are (as will be apparent from a comparison of FIGS. 2 and 3) substantial duplicates of their counterpart elements on the front side of board 15. There is, however, an important difference in the nomenclature used herein to describe such elements which are, respectively, on the front side and the back side of the board. That is, it was earlier stated that the front-to-back transverse direction will be used herein as a reference direction in describing left-relations between elements of the coupler device 10. Using that front-to-back direction as the criterion for determining which elements are "left" and "right" in relation to each other, the back leads 27b and 28b are referred to herein as right and left back leads, respectively, even though they appear to have the opposite handedness in FIG. 3 (but not in FIG. 4). Similarly, the back ground plane regions 51b and 52b are referred herein as being right and left back ground plane regions although they appear to have the opposite relation in FIG. 3 (but not in FIGS. 1, 2 and 4). The same ap-

proach to the left-right relation is used for other elements shown in FIG. 3.

Some differences of the back side of device 10 from its front side are as follows. In FIG. 3, the connector strips 122 and 120 on support board 110 are terminated on the back side of device 10 by stub lengths of those connectors which are electrically connected by solder beads 126b and 125b to the terminations 49b and 44b of, respectively, the left back lead 28b and right back lead 27b. The various solder beads 125, 126 and 130 on the front and back sides of board 15 provide mechanical bonds by which the coupler assemblage 11 is fastened to the support assemblage 12.

Referring back to FIG. 1, the coupler device 10 is shown as being connected at its front side to circuitry 134 external to the device. Specifically, the connectors strips 121 and 123 are shown as electrically connecting the left and right hand ends of the strip conductor 25a to, respectively, the elements belonging to external circuitry 134 of (a) a 50 ohm source 135 of microwaves, and (b) a circuit means 136 offering a 50 ohm resistance seen by that conductor at its right hand end. The strips 120 and 122 electrically connect the left and right hand ends of the strip conductor 25b to elements of circuitry 134 consisting of, respectively, (c) a 50 ohm termination 137 of that conductor at its left hand end, and (d) a 50 ohm load 138 for the microwave energy transferred from conductor 25a to conductor 25b. Thus, the connector strips 121, 123, 122 and 120 on the support board 110 serve to provide for the entire device 10 the signal ports known as, respectively, the input port, the thru port, the isolation port, and the coupled forward port. Considering, however, the coupler board 11 alone (i.e., without the assemblage 12), the lead terminations 29a, 49a, 29b and 49b provide, respectively, for the board device its input port, thru port, isolation port and coupled forward port.

Because any of the connector strips 120-123 can pass beneath coupler assemblage 11 and, in so doing, be protected by one of the notch-shaped voids 76a, 76b, 77a, 77b from being grounded by contact with one of the ground plane regions on that assemblage, any of those connector strips can extend on support board 10 (beyond a stub length of the strip) away from the coupler board 15, either in the front-to-back transverse direction or the back-to-front transverse direction. Thus, the coupler device 10 is flexible in its connectability in that it is not limited to being electrically connected to external circuitry on only the front side (or only the back side) of the device. As just one example of that flexibility, in lieu of what is shown by the figures, connector strip 123 may extend, from a stub length thereof on the front side of board 15, beneath the board 15 and notch-shaped void 76b and thence on support board 10 rearward to an electrical connection of that strip with the external circuit element 136 located to the rear of device 10. Also, connector strip 120 may extend on support board 110, away from coupler board 15, rearward to an electrical connection of strip 120 with the external circuit element 138 located to the rear of device 10. Device 10 has that versatility in its connectability to external circuitry because, as stated, any of connector strips 120-123 can pass beneath board 15 and, in so doing, are protected by the notch-shaped voids 76, 77 on board 15 from being grounded.

Some features of the coupler assemblage 11 not yet mentioned are as follows. The dielectric material 16 of the board 15 is a ceramic filled polytetraflouroethylene material with a dielectric constant of 10.5. The thickness of the dielectric material is .64mm (0.025") and the metallic layers on the transversely opposite sides of board 15 are provided by 1/2 OZ. copper cladding. Originally those layers completely coated both of those sides of the board, but such originally continuous layers have been etched to form the flat conductors and ground plane regions on such sides.

The central strips 26 on board 15 have a longitudinal length of 2cm (0.8") and a width of 1.3mm (0.05") and are spaced from the near edges 55 of the central ground plane regions 50 by strip-bordering gaps 58 having a width of 1.8mm (0.07"). The leads 27 and 28 of the strip conductors have a width of .58mm (0.023"). The strip conductors 25 and ground plane regions 50-52 on board 15 have thereon an anti-oxidant coating (not shown) which may be gold or a tin-lead composition or other composition.

Some other dimensions and values are now given. As shown in FIGS. 2 and 3, the lead-bordering gaps 57 and 66 and the lead-bordering gaps 59 and 72 to either side of, respectively, the front and back leads 27 and the front and back leads 28 are gaps which (except where, narrowed to the described pinches 67 and 61, of respectively, gaps 66 and 59) are substantially greater in width than such leads. It follows that, since those leads have a width of .58mm (0.023") which is about the same as the .64mm (0.025") thickness of the coupler board 15, FIGS. 2 and 3 disclose that the mentioned gaps have (except at their pinches, if any) a width value substantially greater than the thickness value of the board. In point of fact, the gaps 57 and 72 and the gaps 66 and 59 (except at their pinches 67 and 61) have a width of 1.3mm (0.050") which is twice the .64mm (0.025") thickness of the boards. At their pinches 67 and 61, the gaps 66 and 59 have widths which are in the range from .013mm (0.0005") to .25mm (0.010"), and which are smaller in value than the board thickness.

The overall length of the board is about 4.7625cm (1.875"), and the overall width of the board is about 1.232cm (0.485"). Board 15 is thus less than half as high as it is long.

Reference is now made to FIG. 4 for a showing

of mechanical and electrical characteristics of the assemblage 11 which contribute to its functioning as a microwave directional coupler. FIG. 4 is schematic in the respect that the configuration for some of the elements shown thereby (as, for example, the flat conductor lead portions 27 and 28) differs somewhat from the configuration shown by FIGS. 2 and 3 for those same elements. To the extent that there are such differences, FIGS. 2 and 3 show the preferred configuration.

In FIG. 4, areas on the figure which are only stippled represent only areas of ground plane regions on the front side of coupler board 15, areas on the figure which are only filled with small crosses represent only areas of ground plane regions on the back side of coupler board 15, and areas on the figure which are both stippled and contain small crosses represent areas of overlap through the thickness of board 15 between ground plane regions 51a and 50b, and between ground plane regions 50a and 51b.

Considering now the elongated longitudinally extending horizontal bar designated in FIG. 4 by the reference numeral 26, that bar represents both the front central strip 26a of strip conductor 25a (FIG. 2) and the back central strip 26b of the strip conductor 25b (FIG. 3). Those two central strips lie in parallel planes and register with each other through the thickness of the substrate provided by board 15. In such connection what is meant herein by the statement that two elements on opposite front and back sides of a substrate (exemplified by board 15) are "in registration through the thickness of the substrate" (or a similar statement such as that the two elements are "overlapping through the board") is that, if the area occupied by the front element over the front side of the substrate is projected through the substrate to its back side to form on such back side an image of such front side area, the area of such image will fully or partly overlap with the actual area occupied over such back side by the back element. In the case of the substrate exemplified by board 15 which has in the transverse direction front and back sides which are parallel and planar and spaced from each other by a constant thickness of the substrate, the direction of projection taken from any point within the front side area (in order to form the mentioned image of that area) is a direction which coincides exactly with such transverse direction. In other cases, however, (e.g., where the front and back sides of the substrate are planar but non-parallel (or one or both are non-planar) the projection from any point within the mentioned front side area to the substrate's back side in order to form the mentioned image is effected in the direction through the substrate which yields, between that point and the corresponding point on the image, the smallest thickness of the substrate as measured by the distance between those two points.

The central strips 26a and 26b are, by virtue of being in full registration through the thickness of board 15, broadside coupled with each other, electromagnetically speaking. Moreover, each of those central strips is electromagnetically coupled with both of the central ground plane regions disposed below those strips on the board. That is, front central strip 26a is, by a quasi-coplanar wave guide effect, coupled through the dielectric material of board 15 to back central region 50b and, also, is coupled, partly through that material and partly by a coplanar wave guide effect to the front central region 50a. The back central strip 26b is coupled in a similar manner, both to the front central region 50a and the back central region 50b.

If desired, the front and back surfaces 20a, 20b of board 15 may have additional ground plane regions thereon provided by metallic expanses (not shown) in the form of rectangular bars extending on front and back surface areas 75a, 75b between the shown left and right ground plane regions 51 and 52, such bars being integrally joined with those shown regions, and being spaced by gaps from the central strips 26a, 26b lying below them. Such additional ground plane regions will, if present, increase the coupling between the strips 26a, 26b and ground with the possible concomitant, however, of diminishing the coupling between those strips themselves.

Turning now to the leads for the flat conductors 25a, 25b and considering first the left hand leads 27a, 28b, those leads follow respective paths which diverge on board 15 from each other, outward from the junctions, at the strip ends 36a, 37b of those leads, with strips 26a, 26b. The result is that, outward of those strip ends the lead 27a and its associated line-bordering gaps 57a, 66a to either side of that lead are non-overlapping through the thickness of board 15 with the lead 28b and its associated line-bordering gaps 72b, 59b to either side of lead 28b and, thereafter, diverge more from each other for a while, and never come into overlapping relation. Such divergence of the respective paths of the left leads 27a and 28b permits, however, each of those leads over most of its length to be in full registration through the thickness of the board with an area of a ground plane region on the opposite side of the board. That is, and as shown by FIGS. 4, 5 and 6, the left lead 27a on the front of board 15 overlaps through the board with an area of ground plane 50b on the back of board 15 for the leads, full length except for a small portion of such lead at its termination 29a and for another short portion 140a of that lead near its junction 36a with central strip 26a. Similarly the left lead 28b on the back of board 15 is in full registration through the board with an area of left front ground plane region 51 a except for a small portion of such lead at its termination 49b and for another short portion 141b of that lead near its junction 37b with central strip 26b.

Accordingly, each of the left lead portions 27a

and 28b (of strip conductors 25, 25b) on the front and back side, respectively, of board 15 is, over most of its length, in registration through the thickness of the board with a ground plane region on the opposite side of the board so as to have with that region a broadside coupling akin to that existing in microstrip transmission line. The end portions 140a and 141b of those leads do not, however, overlap through the thickness of the board with any area of any ground plane region. That is so of necessity because the only way for such overlap to be produced would be, in the case of lead portion 140a to have the head 60b (FIG. 3) of back central ground plane region 50b modified to join back central strip 26b at junction 37b and, in the case of lead portion 141b, to have left front ground plane region 51a (FIG. 2) modified to join front central strip 26a at junction 36a, but either such joinder would ground the "joined-to" central strip to render the coupler device 10 inoperable.

The inability to broadside couple the mentioned lead portions 140a and 141b with ground plane regions on the opposite sides of board 15 is compensated for by, in the case of portion 140a, providing on the front side of board 15 (FIGS. 2, 4, 6) in the gap 66a the pinch 67a between lead 27a and left ground plane region 51a, and by, in the case of portion 141b, providing on the back side of board 15 and in the gap 59b (FIGS. 3, 4, 6) the pinch 61b between the lead 28b and the head 60b of the back central ground plane 50b. Because of the narrow widths of those pinch gaps 67a and 61a the left front lead 27a over its end portion 140a becomes coupled by a coplanar wave guide coupling with the front left ground plane region 51a on the same side of board 15 as that lead, and the left back lead 28b over its end portion 141b becomes coupled by a coplanar wave guide coupling with the back central ground plane region 50b.

What has been set out above regarding the left lead portions 27a and 28b of the flat conductors 25a and 25b applies equally, mutatis mutandis, to the right lead portions 28a and 27b for those strip conductors. That is, those right lead portions follow divergent paths to result in being non-overlapping through the thickness of the board at a short distance from their junctions with their corresponding strips 26a and 26b, and by remaining so non-overlapping thereafter with progress away from such junctions. Further, the right front lead 28a is, over most of its length, in registration through the thickness of board 15 with an area of the ground plane region 51b on the back of the board, and the right back lead 27b is, over most of its length, in registration through the thickness of the board with an area of the front central ground plane region 50a. The right leads 28a and 27b are thus broadside coupled over most of the length of each with a ground plane region on the opposite side of the board from that lead.

Those leads 28a and 27b have, however, (FIGS. 4, 5 and 7) end portions 141a and 140b near the junctions of those leads with central strips 26a and 26b, and which end portions 141a and 140b are (a) separated by narrow pinch gaps 61a and 67b from, respectively, the front central ground plane region 50a and the back ground plane region 51b, and are (b) respectively coupled by coplanar wave guide couplings to those ground plane regions 50a and 51b on the same side of board 15 as, respectively, such lead portions 141a and 140b.

The plated-through holes 80-89 and 90-98 (and the other plated-through holes shown by the drawings), perform the useful electrical function of shortening the return paths for R.F. currents flowing through the ground plane regions. For example, the holes which extend in a row (FIG. 2) just below the upper edges 55 of the central ground plane regions 50 (and which holes include holes 87-89 and 97) permit R.F. current produced near those upper edges by the field coupling of those regions with central strips 26a, 26b to flow close to those edges between front region 50a and back region 50b without having to be detoured down to the supplemental ground plane 113 on mother board 110 in order to effect such current flow between the edges of those regions.

From the example given, it will be evident that the plated-through holes in board 15 electrically interconnect the ground plane regions on the board independently of any connection of any of those regions to the supplemental ground planes 113-117 on the top of support board 110. Such interconnection of the ground plane regions on board 15 by plated-through holes in the board itself serves to shorten considerably the return paths for R.F. currents in those regions (as compared to the lengths those paths would have if such regions on board 15 could be interconnected only through the ground plane regions on support board 110) and, thereby, to reduce losses in, and otherwise promote the efficiency of, the coupler device 10.

It will be appreciated from the foregoing description that the coupler device 10 comprises a pair of two-conductor transmission lines, each including signal conductor means and ground conductor means, of which respective signal conductor means for those two lines are provided by the flat conductors 25a and 25b on opposite surfaces of the substrate means 15 for the device 10, and of which the ground conductor means for those lines are provided by ground plane regions, such two transmission lines having portions which are electromagnetically coupled with each other to effect transfer of microwave energy from one to the other of such lines. The provision in the coupler device of having ground plane regions on the same surfaces of the coupler substrate or body of the device as are the mentioned flat conductors is a feature which conserves the materials required to be included in the coupler in order to realize a desired function-

ing thereof, and which, moreover, promotes the ease and inexpensiveness of manufacture of the coupler device.

To describe further some of the features of the coupler device 10, it will be noted from FIGS. 4 and 5 that the full lengths of the various leads on board 15 extend from their junctions with their corresponding central strips to the ports at which those leads terminate at the bottom margin of the board. The left front and back leads 27a and 28b are unequal in length and, likewise, the right front and back leads 28a and 27b are unequal in length. Such inequality in length facilitates a layout for the paths followed by the leads which will enable them to extend from such junctions to such ports without any lead, over at least most of its extent, having any overlap through the board with any other lead.

The flat conductors 25a and 25b have the same overall lengths. Those lengths are measured for conductor 25a between and including the ports 29a and 49a and, for conductor 25b, between and including the ports 29b and 49b. It is preferable (although not necessarily) desirable that, in a hybrid coupler, the two conductors which are coupled together have such equal overall lengths in order, if nothing else, to simplify the work of designing the coupler.

In order, however, to attain both of the desirable features of having the conductors 25a and 25b equal in overall length and, concurrently, having unequal the lengths of the left leads as to each other and the length of the right leads as to each other, it is necessary that, in each of the conductors 25a and 26b, the left and right leads therein have respective lengths unequal to each other, as is the case in coupler 10 with those conductors. Such inequality leads, of course, to the feature that, on board 15, the longitudinal centers 32 of the central strips 26 do not coincide with the respective midpoints 145a, 145b of the overall lengths from port to port of the conductors 25a and 26b. Instead, the strip centers 32 are offset from such midpoints which have a location on the longer lead 28 of the two leads included in each of the flat conductors 25. I have found that to have such broadside coupled portions 26 of the coupled conductors 25 not at the midpoints 145 of the overall lengths of such conductors is an asymmetry which produces no significant adverse effect on the operation of the coupler.

To have the leads on the coupler board be unequal as described above is often advantageous in that, for example, it permits greater freedom of design of the layouts on the board of the leads and the ground plane regions. It is not, however, required by the invention, considered broadly, that there be present any of the described lead inequalities.

Considering now in further detail the central strips 26a and 26b, the end portions 36a and 37a of strip 26a have the shapes (FIGS. 2, 6, 7) of congruent isosceles triangles having their vertex angles pointing away from the longitudinal center of the strip. Also, the end portions 36b and 37b of strip 26b have the shapes of isosceles triangles (FIG. 3) which have their vertex angles pointing away from the center of strip 26b, and which are congruent with each other and the triangles formed by portions 36a,37a. The triangular portions 37b and 36b of strip 26b are directly behind, through the board in the front-to-rear transverse direction, with, respectively, the triangular portions 36a and and 37a of strip 26a so that there is no point within any of those triangles which does not overlap through the board with a corresponding point in another of those triangles. Thus, those triangular portions partake in the broadside coupling together of conductors 25a, 26a through their central strips 26a, 26b. Such full overlapping within the triangular portions 36a, 37b, 37a, 36b does not occur outward of those portions in the direction away from the centers of strips 26a, 26b.

Referring to FIG. 6, on the front surface of the board, the lead 27a has a junction 150a with the lower side of the triangle defined by strip end portion 36a, the location of such junction being indicated by a dash line. With regard to the transmission line provided by conductor 25a on the front surface of the board and the metallic portion opposite it on the back surface of the board, the lead 27a extends continuously to strip 26a but the ground conductor provided by the portion opposite lead 27a of region 50b does not extend all way on the board's back surface to strip 26b. That is so because the gap 61b which borders lead 28b separates that portion of ground plane region 50b from strip 26b and opposite through the board with the end portion 140a of lead 27a, and the gap 61b determines the length along conductor 25a of portion 140a, which length is equal to the width of gap 61b. Because the microstrip coupling of conductor 25a is, by definition, with grounded metallic portions on the opposite side of board 15, such microstrip coupling ends, technically speaking, at the edge of gap 61b away from the central strip 26a. Notwithstanding such ending, the transmission line provided by conductor 25a and metallic portions on the board's back surface 20a will not have an "open" looking toward strip 26a when the line reaches gap 61b since electric field lines from lead end portion 140a can bridge that gap to terminate on central strip 26b, and that strip while not grounded, is broadside coupled with central strip 26a to provide by the two strips a continuation beyond lead 27a of the transmission line including signal conductor 25a. The presence, however, of gap 61b existing between strip 26b and the portion of ground plane region 50b opposite lead 27a introduces into such transmission line an electrical and mechanical discontinuity which, if not compensated for, would produce an anomaly in the impedance of the line.

Similar discontinuities exist between the trans-

mission lines provided by the other leads on the board and the portions opposite them of ground plane regions on the other side of the board from those leads. Specifically, lead 28b on the back surface of the board has a junction 151b (FIG. 6) with the upper side of the triangle defined by end portion 37b (FIG. 3) of strip 26b, but the portion of ground plane region 51 a opposite lead 27b on the front surface of the board is separated, from the upper side of the triangle defined by end portion 36a of strip 26a, by the gap 67a which is opposite the end portions 141b of lead 28b and determines the length along lead 28b of portion 141b because such length equals the width of gap 67a. Further, on the right hand side of board 15, lead 28a (FIG. 7) has a junction 151a with the upper side of the triangle defined by strip end portion 37a, but the portion of region 51b which though the board is opposite lead 28a is separated by gap 67b from the upper side of the triangle defined by end portion 37b (FIG. 3) of strip 26b. Still further, lead 27b has a junction 150b (FIG. 7) with the lower side of the triangle defined by strip end portion 37b, but the portion of region 50a which, though the board, is opposite lead 27b is separated by gap 61a from the lower side of the triangle defined by strip end portion 37a.

Thus, the lines, provided by leads 27 and 28 and the ground plane regions opposite them through the board, have the discontinuities just described in such lines. This discontinuities are, however, compensated for in a manner which is the same for all the transmission lines, but which is exemplified by the line including lead 27a now to be considered.

Referring to FIGS. 4 and 5 and considering the portion of lead 27a designated as section 44a, for a small distance extending from the bottom margin 22 of board up to the top of void 77b, the front lead 27a is absent a ground plane region portion opposite it through the board, and such absence can, if desired be compensated for by utilizing the expedient of narrowing over that distance the gaps 57a, 66a to either side of lead 27a, down to very small widths as suggested by the FIG. 4 showing. It has been found, however, that it is unnecessary to resort to such expedient for purposes of avoiding an anamalous impedance in the transmission line, and that such narrowing of the gaps 57a, 66a sometimes creates difficulties in preventing grounding of the solder connection made between lead 27a and connector strip 121 (FIG. 2). Hence, it has been found preferable not to employ such expedient, and to provide that gaps 57a, 66a have their full widths at the very bottom 22 of the coupler board.

Whether or not such expedient is adopted, the gaps 57a and 66a bordering lead 27a will have their full widths over a greater extent of the full length of lead 27a as one proceeds from the end of that lead at port 29a to the junction 150a of that lead with central strip 26a. The presence over that extent of the lead 27a itself, the dielectric board 15, the regions 51a and 50a in the same plane as lead 27a and the gaps 66a, 57a provide, together, the structure which is shown in FIG. 8, and which has the elements necessary to create a double-sided coplanar wave coupling for transmitting microwaves along the lead in the instance where it mostly overlaps through the board with portions of ground plane regions on the opposite side of the board. Whether or not, however, such elements are sufficient to create such a coupling depends on the effect of a number of factors including the dielectric constant of the material of the board, the width of the lead in relation to the board thickness (which determines the distance of the lead from the ground plane region 50b on the opposite side of the board) and, as an important parameter here, the ratio of the widths of gaps 66a and 57a to the board thickness which determines that distance. An increasing of those gap widths in relation to such thickness tends to inhibit the creation of an effective coplanar wave guide for microwave transmission, the converse being true for a decreasing of such gap widths in relation to such thickness. As an empirical rule, in order to insure that microwave transmission over that greater extent of lead 27a will at least be primarily by microstrip wave guide coupling as compared to coplanar wave guide coupling, the widths of gaps 66a and 57a should be enough greater than the thickness of board 15 to yield that result when other factors are taken into account. As stated the gaps 66a and 57a have, over at least most of their extents, a width which is twice the board thickness, and that ratio causes, in the case of board 15, the transmission of microwaves over such extents of the leads to be substantially entirely by a microstrip wave guide coupling of the leads as will now be described.

FIG. 8 depicts the operating characteristic of the coupler device 10 over such greater extent of lead 27a (and all the other leads). Specifically, the transmission of microwaves over such greater extent of that lead is substantially entirely by a microstrip wave guide coupling of lead 27a to ground plane region portions on the opposite side of the board, as distinct from a coupling of lead 27a to regions 50a and 51a. That is, any microwave electromagnetic field in the coplanar mode is very feeble as represented in FIG. 8 by the connection shown therein of lead 27a to each of regions 50, 51 a by only one coplanar electric field line designated E_C. In comparison, over that greater extent of lead 27a, the transmission of microwaves along the lead takes place substantially entirely by a microstrip wave guide coupling of the lead to ground plane region 50b, such effective microstrip transmission being represented in FIG. 8 by a shown high density of the microstrip electric field lines designated E_M. That such transmission over that extent of the lead by coplanar wave guide coupling is negligible as compared to such transmission by microstrip wave

guide coupling is known from the fact that the 50 ohm impedance which is calculated for the transmission line including lead 27a on the assumption made in designing that line that its wave guide coupling will be wholly microstrip is a calculated figure which deviates by less than 5% from the measured impedance value for that line.

Some advantages of transmitting microwaves along lead 27a primarily by a microstrip wave guide coupling of that lead through board 15 with ground plane region 50b are as follows. First the width of lead 27a (and the other leads) can be made, for example, ten times smaller than if coplanar wave guide coupling were used. Second, the board 15 can have much less thickness than would be needed if the transmission were to be coplanar. Third, it is not necessary to be as careful about etching tolerances as if the coupling were coplanar.

Further (and as distinct from the Wong coupler in which the broadside coupled pads must each be coupled on both their lengthwise sides with coplanar ground plane regions), such microstrip coupling avoids the need for, and permits elimination of, wave guide couplings of strips 26 on their upper sides with ground plane regions above them (in addition to the described couplings of those strips on their lower sides with the ground plane regions 50 below them), and the elimination, as shown, of such couplings of strips 26 on their upper sides permits the height of board 15 to be reduced and a cost saving effected thereby.

As was mentioned earlier, the discontinuity caused in the transmission line including lead 27a by the gap 61b would, if left alone, produce an anomaly in the impedance of the line. Such possible problem caused by that discontinuity is overcome on board 15 by having the mode of microwave transmission along the full length of lead 27a shift from transmission substantially entirely by microstrip wave guide coupling over a greater extent of lead 27a, to microwave transmission occurring over a lesser extent of lead 27a adjacent its junction 150a with strip 26a, and a significant part of which transmission is effected by coplanar wave guide coupling. Such transition from one to the other mode of transmission along lead 27a is depicted in FIG. 9 and is implemented, as earlier described, by narrowing the gap 66a down from its width shown in FIG. 8 to the width which it has in the pinch 67a, and which width is less in value than the thickness of board 15. Such narrowing of gap 66a causes the lead 27a to have to, over its lesser extent and with ground plane region 51a a coplanar wave guide coupling effective to transmit microwaves along the length of the lead to a degree partly or entirely compensating for the loss in effectiveness of the microstrip wave guide coupling near junction 150a due to the discontinuity in such latter coupling caused by the lead 27a having opposite it through the board, near that junction, the gap 61b rather than a ground plane region. The occurrence of the described transition is represented in FIG. 9 by an increasing, as compared with FIG. 8, in the number of coplanar electric field lines E_C and a decreasing, as compared with FIG. 8, in the number of microstrip electric field lines E_M.

An interesting point with regard to the narrowing of gaps on one side of the leads on board 15 down to the described pinches in such gaps is that such narrowing is useful in two respects. That is, the narrowing of gap 66a, for example, down to pinch 67a provides a coplanar wave guide coupling for transmission of microwaves along lead 27a to compensate for the discontinuity caused by gap 61b in the transmission of microwaves along lead 27a by microwave wave guide coupling. At the same time, however, the presence of gap 66a produces a discontinuity in the transmission by microstrip coupling of microwaves along lead 28b, but the narrowing of gap 66a down to pinch 67a reduces the size of that discontinuity in the transmission line including lead 28b.

An aspect of the mentioned transition is that transmission of microwaves along lead 27 is supported by an electromagnetic field which, with advance along lead 27a towards strip 26a, shifts from being substantially entirely below lead 27a to being at least partly above it as shown by FIG. 9. The plated through holes aid in such shift by permitting RF currents originally generated in ground plane region 50b by the microstrip coupling between it and lead 27a to flow directly from region 50b to region 51a to there support the coplanar field formed above the latter region.

The central strip 26a is coupled to the ground plane region 50a below it (FIG. 2) and to the ground plane region 50b on the opposite side of board 15 by respective wave guide couplings of which the first is a coplanar coupling and the second can be referred to as a quasi-coplanar coupling inasmuch as ground plane region 50b is not in the plane of strip 26a but, on the other hand, is only slightly displaced from that plane. The plated through hole 88 and other such holes shown in FIG. 2 as extending through board 15 just below the upper edges of regions 50a and 50b serve to make more effective the coplanar and quasi-coplanar wave guide couplings of strip 26a to ground plane regions 50a and 50b by providing multiple metallic joinders of these regions together at their upper edges so that those regions are, in effect, seen by strip 26a as a single thick metallic copper body extending all the way through board 15. The same holes in like manner make more effective the coplanar and quasi-coplanar wave guide couplings (not shown) of strip 26b to, respectively, the region 50b and the region 50a.

From what has been said, it will be evident that the transmission of microwaves along conductor 25a undergoes a transition from (a) transmission primarily by microstrip coupling along lead 27a in which the

electric fields produced by such coupling terminate on the inner or rearward surface of conductor 25a to (b) transmission by a coplanar wave guide coupling along central strip 26a in which the electric fields produced by such coplanar coupling terminate on the outer or frontward surface of conductor 25a. A difficulty in effecting such transition is that RF current tends to flow only on the surface of a metallic body (such as conductor 25a) rather than through it. The plated-through hole 86, however, aids in such transition in a manner of which a simplified explanation is as follows.

Assume that, at a point along lead 27a (FIG. 6) away from gap 61b, RF current has been caused to flow from conductor 25a to ground plane region 50b by the action of the fields produced by the microstrip coupling of that lead to that region. Such current will, in the vicinity of gap 61b, encounter anomalously high impedance in seeking to return to conductor 25a by way of the path provided by the fields existing near that gap between conductor 25a and the metallic portions opposite it on the board's back surface 20b. As, however, an alternate path of return flow to conductor 25a, such current may and does flow, in the back to front direction, from region 50b through hole 86 to the outer surface of region 50a to help enable and support at that outer surface the coplanar coupling of region 50a to strip 26a, such current being returned by that coplanar coupling to the conductor 25a. The plated-through hole 86, by virtue of permitting such RF current to pass freely from one to the other of locations on opposite sides of flat conductor 25a, plays an important role in enabling the wave guide coupling of conductor 25a to ground plane regions to shift, as described, from microstrip coupling to coplanar coupling.

The plated-through hole 96 (FIG. 7) performs an analogous function to that just described for hole 86 in aiding the transition of microwave transmission over conductor 25b from transmission primarily by microstrip coupling along lead 27b to transmission by coplanar coupling along the strip 26b of conductor 25b.

Assume, in connection with hole 84 (FIG. 6), that, at a point along lead 28b displaced from gap 67a, RF current has been caused to flow in the rear to front direction from lead 28b of conductor 25b to ground plane region 51 a by the fields engendered by the microstrip coupling between that lead and region. Such current will return to conductor 25b by passing through hole 84 in the front to rear direction to the outer surface of ground plane region 50b to thereby help enable and support the formation of the coplanar coupling between such ground plane region 50b and the central strip 26b of conductor 25b, that current being returned to conductor 25b by such coplanar coupling. Such passage of current through hole 84 also helps to enable and support the coplanar coupling of lead 28b at pinch gap 61b (FIG. 3) with ground plane region 50b.

The hole 94 performs in a similar manner, in the case of conductor 25a, to aid the transition of the coupling of that conductor from primarily microstrip coupling along lead 28a (FIG. 2) to coplanar wave guide coupling along strip 26a by helping to enable and support the formation of that coplanar wave guide coupling at the right hand end 37a of strip 26a of conductor 25a with ground plane region 50a. Such passage of current through hole 94 also helps to enable and support the coplanar coupling of lead 28a at pinch gap 61a with ground plane region 50a.

The presence of the holes 86, 94 and of the holes 84, 96 is a factor compensating for the mentioned impedance anomalies which, to the extent uncompensated for, would be respectively caused along the transmission lines including conductors 25a and 25b by, respectively, the gaps 61b, 67b and the gaps 67a, 61a.

As a further matter, the plated through holes 82, 83 and 92, 93 disposed on board 15, respectively, longitudinally between the front and back leads 27a and 28b on the left side of the board and longitudinally between the front and back leads 28a and 27b on the right hand side of the board are holes which serve not only to electrically couple together ground plane regions on opposite surfaces of the board but, also, to prevent extraneous coupling together of the transmission lines on the longitudinally opposite sides of the holes.

The described coupler assemblage 11 has the advantages among others that, because the leads on the board and the ground plane regions thereon all have terminations at the bottom of the board 15, it is very easy to electrically connect coupler assemblage 11 to external microwave circuitry as, for example, to the connector assemblage 12. Another advantage among others of coupler assemblage 11 is that because all such terminations are on one peripheral margin of board 15, the assemblage can be compact and cheaper to manufacture than, say, the device of the Wong patent.

Some further details of the electrical characteristics of the coupler device 10 represented by FIGS. 1-3 are as follows. The described device is one which splits the input power thereto equally into two paths. This means that its thru and coupled output ports are nominally 3 dB down in power from the power supplied to the input port of the coupler. The coupler device is a 90° quadrature coupler in that the phase of R.F. energy which appears at its coupled forward port is nominally in 90° phase relation with the phase of the R.F. energy supplied to its thru port. The coupler device 10 is designed for use with microwave energy having a frequency of 881 MHz ± 12.5 MHz.

The invention includes variants of the above-described embodiment which, for example, without

limitation, are of the following character. The coupler substrate of the coupler device is conveniently provided by a monolithic body of dielectric material, but it may also be provided by a composite body of such material. Further, while it is convenient for the opposite surfaces of the substrate which bears the strip conductors and the ground plane regions to be parallel planar surfaces spaced from each other by a constant thickness between them of the dielectric material of the substrate, it is within the purview of the invention for such surfaces to be planar but non-parallel or for one or both of them to be non-planar. Still further, the strip conductors and ground plane regions may be provided by metallic foils on such surfaces rather than by metallic coatings deposited thereon. While the lead portions of the strip conductors have been described as narrower in breadth than the central strip portions thereof, they need not be narrower than such central strip portions. The foregoing are only a few examples of particular forms of dielectric coupler devices which are covered by the invention hereof.

Claims

1. A microwave coupler device (10) comprising, a horizontally and vertically extending dielectric coupler board (15) having thickness in the horizontal transverse dimension and front and back surfaces (20a, 20b) separated by said thickness, and also having respective peripheries including respective longitudinally extending horizontal bottom margins (22a, 22b), front and back elongated metallic conductors (25a, 25b) extending on, respectively, said front surface and said back surface between opposite terminations (29, 49) of each conductor which are at the periphery of the corresponding surface, said front and back conductors respectively comprising front and back central strips (26a, 26b) centrally located on said board and broadside coupled with each other through said board, said front and back conductors also respectively comprising two front leads (27a, 28a) and two back leads (27b, 28b) having junctions (150, 151) with opposite ends of, respectively, said front strip and said back strip and extending from such junctions to corresponding ones of said terminations on the surfaces bearing, respectively, said front conductor and back conductor, front metallic ground plane regions (50a, 51a, 52a) and back metallic ground plane regions (50b, 51b, 52b) disposed on, respectively, said front surface and back surface to be spaced from the conductor on each such surface by lead-bordering gaps (57, 66, 59, 72) beside the leads on that surface, and by strip bordering gaps 58 below said strips, said leads overlapping over at least most of their full lengths with portions of ground plane regions on the opposite surface of said board, and said device being characterized by the features that the terminations (29a, 49a) and (29b, 49b) of, respectively, said front leads (27a, 28a) and back leads (28b, 28b) are all at the bottom margins (22a, 22b) of such surfaces and are each longitudinally spaced from the others in the length of said board (15).

2. A microwave coupler device as in claim 1 characterized by the feature that said front regions (50a, 51a, 52a) and back regions (50b, 51b, 52b) have respective terminations on their corresponding surfaces (20a, 20b) which are at said bottom margins (22a, 22b) of said surfaces, and which are spaced in the length of the corresponding surface from each other and from the leads on such surface.

3. A microwave coupler device as in claim 1 or claim 2 characterized by the feature that the lead bordering gaps (57, 66, 59, 72) beside the leads (27, 28) on each of the front and back surfaces 20 have widths, over extents of said leads starting at their terminations (29, 49) and constituting at least most of their full lengths, which are enough greater than the thickness of said board (15) to provide for transmission of microwaves over such extents at least primarily by a microstrip wave guide coupling of said leads with portions of said ground plane regions with which said leads overlap through said board.

4. A microwave coupler device as in claim 3 in which said lead bordering gaps have widths over said extents of said leads which are at least about twice as great as said thickness of said board.

5. A microwave coupler device as in any of the preceding claims in which said leads have, in their full lengths, greater and lesser extents adjacent to, respectively, said terminations (29, 49) of said leads and said junctions (150, 151) of said leads with their corresponding central strips 26, said device being characterized by the feature that lead bordering gaps beside and respective to each of leads 27, 28 undergo a transition over, respectively, said greater and lesser extents of such lead from being greater in width to lesser in width than said thickness of said board (15).

6. A coupler device as in any of the preceding claims characterized by the features that each of said central strips 26 is wave guide coupled with both the one of said regions 50 below and on the same surface 20 as such strip and the one of said re-

gions (50) below such strip and on the opposite surface of such board, and in which said strips 26 have no significant wave guide couplings with ground plane regions above said strips.

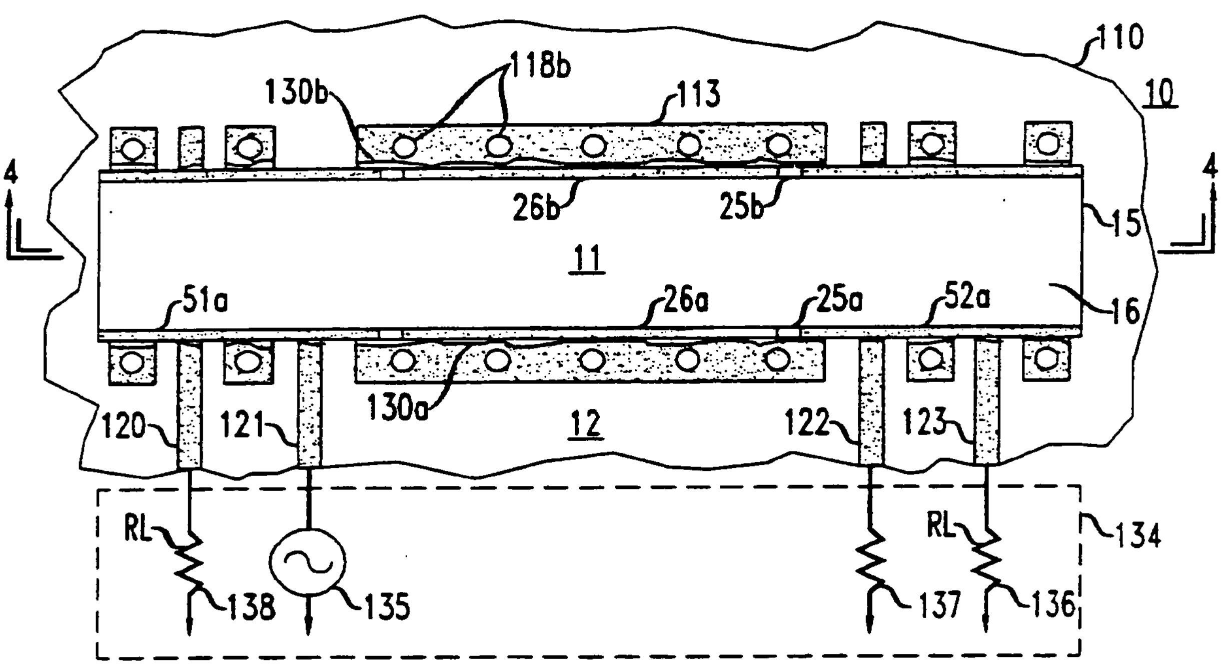
7. A microwave coupler device as in any of the preceding claims characterized by the feature that said device includes a plurality of through-holes having metallic walls and passing between ground plane regions on opposite ones of the surfaces 20, said through-holes being disposed in spaced relation from each other alongside one or ones of the gaps 57, 58, 59, 66, 72 which separate said conductors 25 from said ground plane regions.

8. A microwave coupler device as in any of claims 2 through 7 characterized by the features that the terminations (29, 49) of the front leads (27, 28) and back leads (27, 28) are electrically connected with connector strips (120, 121, 122, 123) on the top surface of a horizontal insulative support board 110 upon which is mounted the coupler board 15, and that the terminations (53, 62, 70) of the ground plane regions (50, 51, 52) on the coupler board are electrically connected by supplemental ground plane regions (113, 114, 115, 116, 117) on the top surface of support board 110, and by through-holes 118 having metallic walls and passing through the support board 110, to a main metallic ground plane region (112) on the bottom surface of board 110.

9. A microwave coupler device as in claim 8 characterized by the feature that the lead terminations (29, 49) at the bottom margins 22 of the front and back surfaces of coupler board 15 overlap through the board with voids in ground plane regions on the opposite surface of such board from such leads and extending upwards from said bottom margins, such voids permitting said connectors 120, 121, 122, 123 to pass beneath said coupler board 15 to the vicinity of said terminations (29, 49) without contacting any ground plane region on said board.

10. A microwave coupler device (10) comprising, a horizontally and vertically extending dielectric coupler board (15) having thickness in the horizontal transverse dimension and front and back surfaces (20a, 20b) separated by said thickness, and also having respective peripheries, front and back elongated metallic conductors (25a, 25b) extending on, respectively, said front surface and said back surface between opposite terminations (29, 49) of each conductor which are at the periphery of the corresponding surface, said front and back conductors respectively comprising front and back central strips (26a, 26b) centrally located on said board and broadside coupled with each other through said board, said front and back conductors also respectively comprising two front leads (27a, 28a) and two back leads (27b, 28b) having junctions (150, 151) with opposite ends of, respectively, said front strip and said back strip and extending from such junctions to corresponding ones of said terminations on the surfaces bearing, respectively, said front conductor and back conductor, front metallic ground plane regions (50a, 51a, 52a) and back metallic ground plane regions (50b, 51b, 52b) disposed on, respectively, said front surface and back surface to be spaced from the conductor on each such surface by lead-bordering gaps (57, 66, 59, 72) beside the leads on that surface, and by strip bordering gaps 58 below said strips, said leads overlapping over at least most of their full lengths with portions of ground plane regions on the opposite surface of said board, said device being characterized by the feature that the bordering gaps (57, 66, 59, 72) beside the leads (27, 28) on each of the front and back surfaces 20 have widths, over extents of said leads starting at their terminations (29, 49) and constituting at least most of their full lengths, which are enough greater than the thickness of said board (15) to provide for transmission of microwaves over such extents at least primarily by a microstrip wave guide coupling of said leads with said ground plane regions with which said leads overlap through said board.

FIG. 1


110
10
118b
130b
113
4
4
26b
25b
15
11
51a
26a
25a
52a
16
120
121
130a
12
122
123
134
RL
RL
138
135
137
136

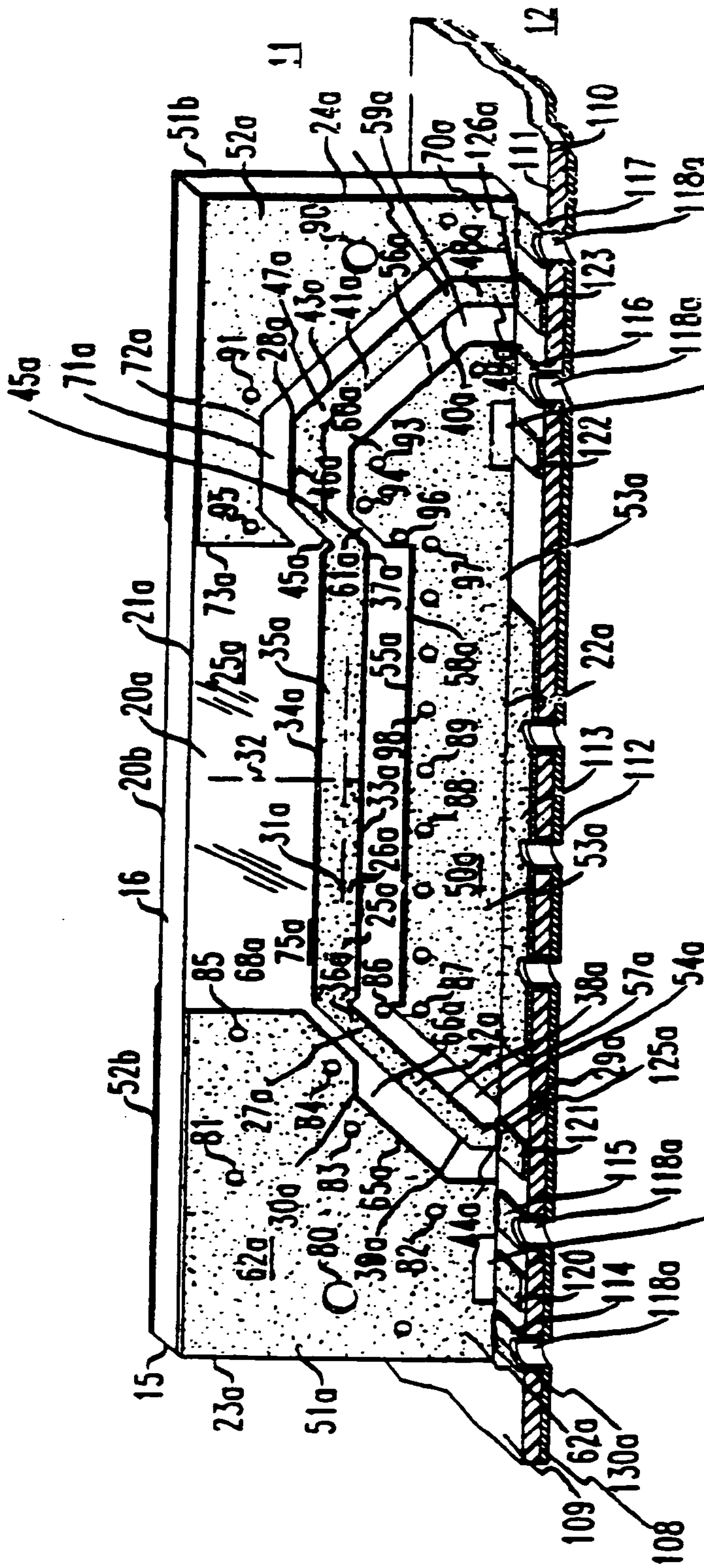


FIG. 2

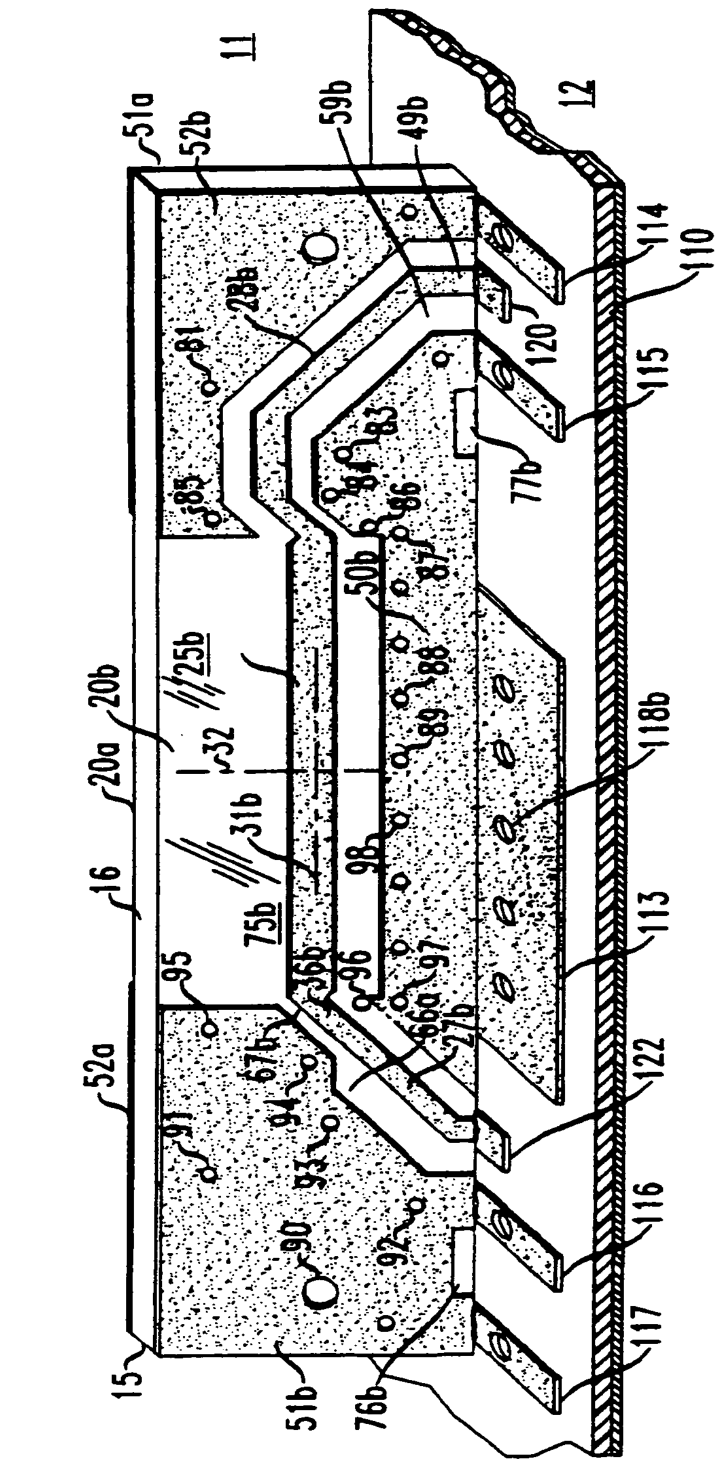

11
12
51a
52b
59b
49b
28b
81
85
83
84
86
87
50b
88
89
25b
20b
20a
32
31b
98
75b
16
95
36b
96
97
66a
27b
67b
94
93
91
52a
90
92
15
51b
76b
77b
114
110
120
115
118b
113
122
116
117

FIG. 3

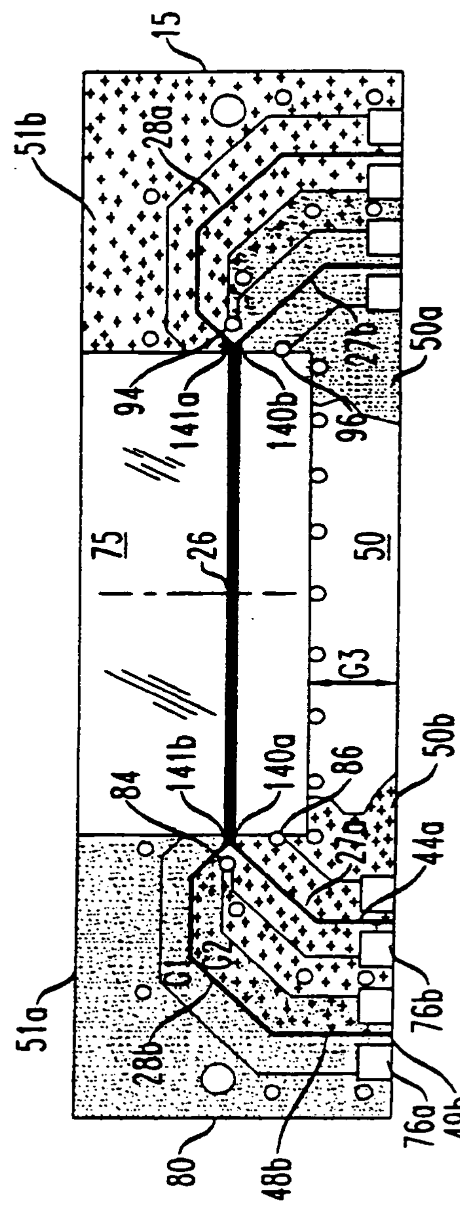

15
51b
28a
50a
27b
96
140b
141a
94
75
26
50
G3
50b
86
140a
141b
84
44a
27a
76b
49b
76a
48b
80
28b
G1
G2
51a

FIG. 4

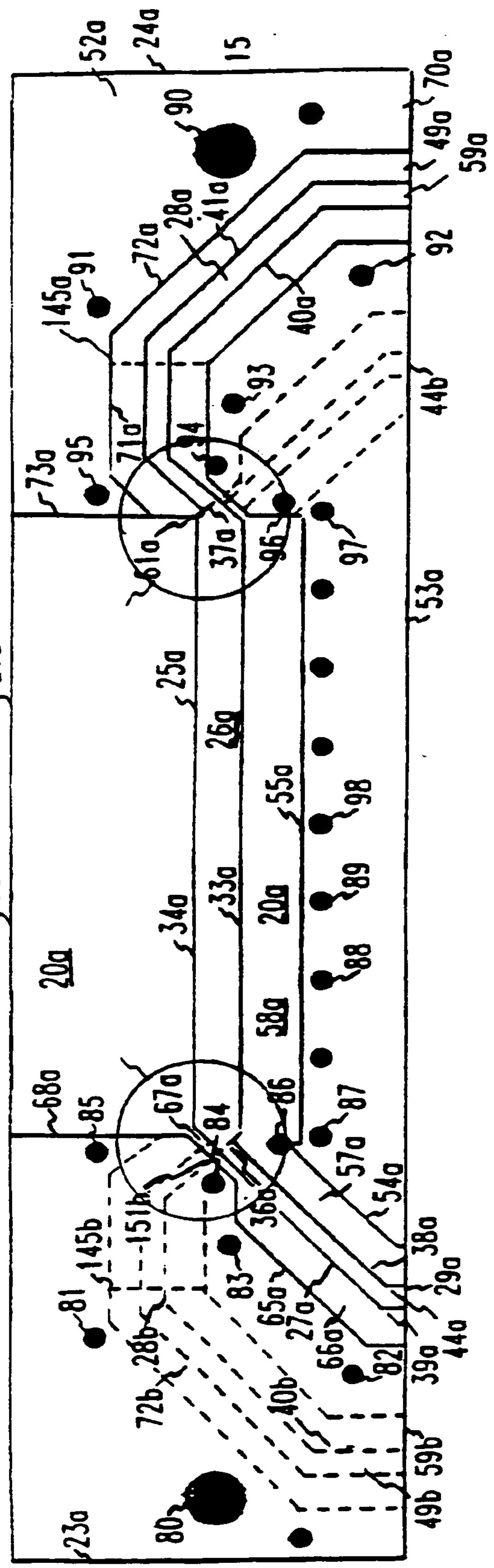


FIG. 5

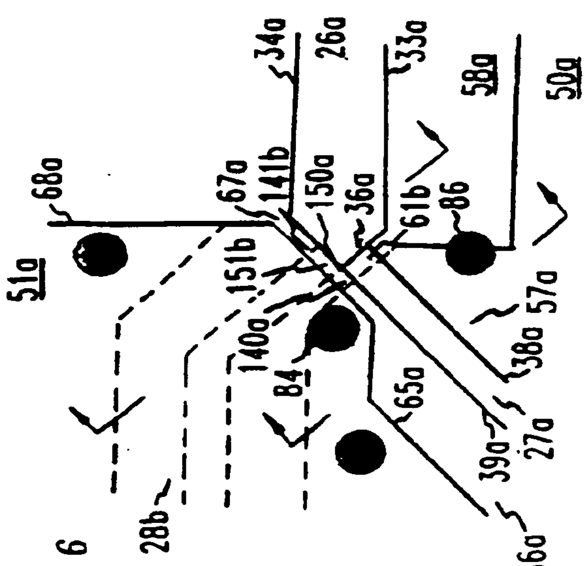


FIG. 6

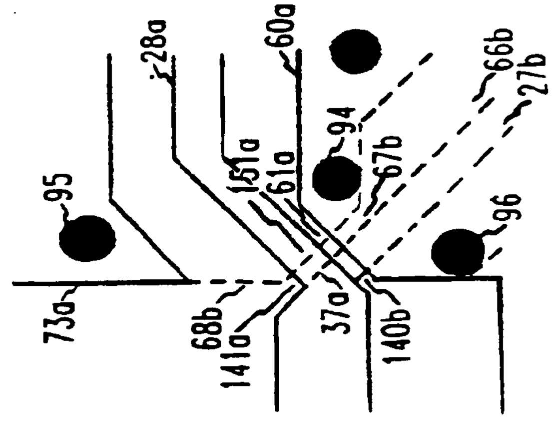


FIG. 7

FIG. 8

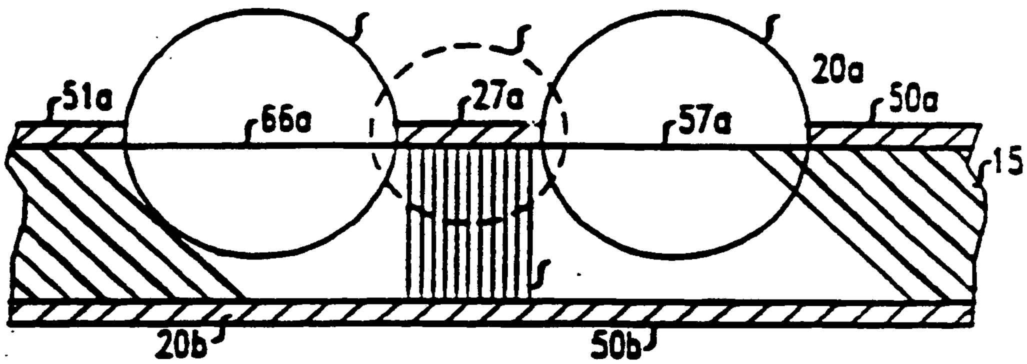
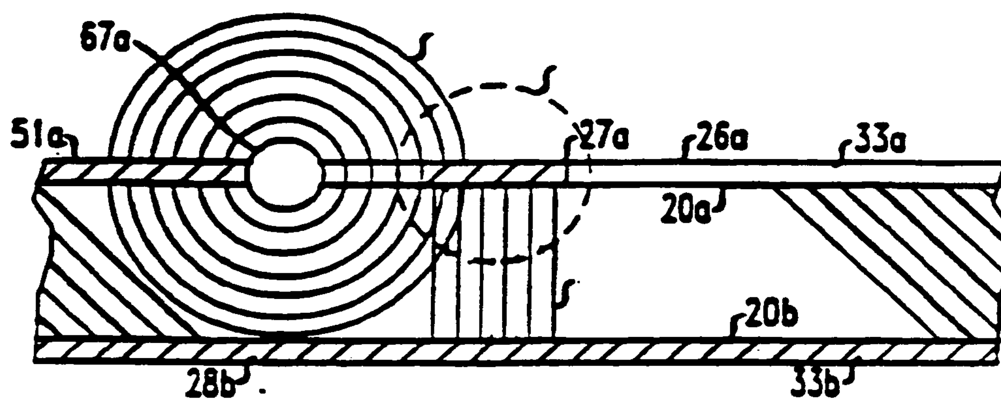

51a
66a
27a
57a
20a
50a
15
20b
50b

FIG. 9


67a
51a
27a
26a
33a
20a
20b
28b
33b

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 95 30 1110

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US-A-4 967 171 (BAN ET AL.) * column 5, line 30 - line 51 * * column 11, line 4 - column 12, line 15; figures 7,13,14 * ---	1,10	H01P5/18
D,A	EP-A-0 354 524 (HUGHES AIRCRAFT CO.) * the whole document * ---	1,10	
A	EP-A-0 439 928 (AMERICAN TELEPHONE AND TELEGRAPH COMP.) * column 4, line 42 - line 53; figure 4 * -----	1,10	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6) H01P

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	1 June 1995	Den Otter, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)